Supporting Active and Healthy Aging with Advanced Robotics Integrated in Smart Environment:

RoboTown Living Lab a concrete experience for developing enhanced ICT and Robotics Services

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ABSTRACT

The technological advances in the robotic and ICT fields represent an effective solution to address specific societal problems to support ageing and independent life. One of the key factors for these technologies is the integration of service robotics for optimising social services and improving quality of life of the elderly population. This chapter aims to underline the barriers of the state of the art, furthermore the authors present their concrete experiences to overcome these barriers gained at the RoboTown Living Lab of Scuola Superiore Sant'Anna within past and current projects. They analyse and discuss the results in order to give recommendations based on their experiences. Furthermore, this work highlights the trend of development from stand-alone solutions to cloud computing architecture, describing the future research directions.

Keywords: Ambient Assisted Living, Ageing well, Senior Citizens, Sensor Network, Companion Robots, Distributed Architecture, Service Design, Multi-Robot services, User Needs Analysis.

INTRODUCTION

Europe is facing unprecedented demographic changes due to the ageing population and low birth rates. On one hand, according to the up-to-date statistics, people older than 65 years are the fastest growing segment of the European population and they will account for a third by 2060. On the other hand, the number of working-age people is expected to decline steadily and the number of older people to increase, leading to an increase in the old-age dependency ratio (Eurostat, 2013).

As people age, they become more susceptible to disease and disability; in fact they have at least one that correlates strongly with the functional decline. However, despite the health problems, the majority of older adults hope to remain in their own homes as long as possible. Even if this wish could improve the elderlys' perceived quality of life, nevertheless it is strongly correlated with the risk of domestic accidents, such as falls, and social isolation, such as depression and loneliness. The effect of these risks is the growing emergency admission to hospitals with a not sustainable impact on the healthcare systems. For these reasons, long-term services and support should be provided in order to promote the ageing well, but the workforce shortages and financial burdens cannot supply the demand for Nurse Practitioners (+94% in 2025) (Auerbach, 2012) and Physician Assistants (+72% in 2025) (Hooker, 2011). Furthermore most European senior citizens live in urban areas (Eurostat, 2013) and services are concentrated there, to the detriment of persons living in rural areas with a higher risk of social exclusion. For this reason senior people living in rural areas are highly at risk of isolation. So the ageing population in rural areas and the lack of access to community services is a challenge (EU Panel, 2007).

Fortunately, many technologies have the potential to help older adults maintain their independence and health. Technology could support elderly people in mobility inside and outside the house and in daily activities, encouraging the social relationships and improving the feeling of safety delaying the physical and mental decline. The validation of this hypothesis is provided on one hand by the rapid development of smart technologies to improve areas as diverse as healthcare, education and crime prevention, and on the other hand by their economic accessibility among common people (Mobile Planet, 2014). According to this phenomenon it is estimated that medical electronics equipment production will increase from $91 billion in 2011 to $119 billion in 2017 with an average rate of 4.6% per year (iNEMI, 2013). Particularly the EU smart home market is estimated to grow from $1,544.3 million in 2010 to $3,267 million in 2015 (Markets and Markets, 2011). Furthermore, the mHealth market will increase in the next few years. 63% of users are comfortable with storing their health record in the cloud (63%), and 30% of them use computers to check medical or diagnosis information (CISCO, 2014).

According to ABI Research (ABI, 2013) a promising market opportunity is also represented by the use of robots for home healthcare applications, in particular the household robots. ABI Research predicts that by 2015, robot sales will exceed $15 billion, due in large part to advanced sensor technology and cheap, powerful cameras. While most robots are currently limited to industrial settings, it is the home environment that presents the greatest opportunity for robot developers. According to market analysis carried out by ABI Research, the task robot is the robot with highest revenue (+ 37.5%) between 2010 and 2017. These results confirm the projection made by Robotic Japan Association which shows that the domestic robot will be the main segment over the global robotic market.

Furthermore the elderly population will benefit from the services, based on the use of Ambient Assisted Living (AAL) technologies that could contribute to increase their perceived QoL (Moschetti, 2014), as shown in Figure 1.

The green line represents the standard QoL of an elderly person, which would normally decrease after a certain age due to cognitive and physical disabilities related to age, as well as decreasing social interactions. The other lines show how the curve can be modified, introducing service and technological tools which aim to prevent, support and enhance the independent living of the elderly population.

In particular, the blue line shows how the decrease of QoL could be delayed when some prevention activities are undertaken in order to delay or reduce morbidity. The red line highlights how QoL decreases more slowly in cases where compensation or support actions are engaged in. Similarly, the yellow line shows how independent living and active ageing can help to maintain high levels of QoL for a longer

period. All of these actions can be supported by an integrated technology solution that can help people engage in activities that aim at improving perceived QoL.
These concepts provide evidence that by using AAL technologies and exploiting AAL services it is possible to have a higher QoL at all stages, and to live longer while not being a burden to society and the welfare system.

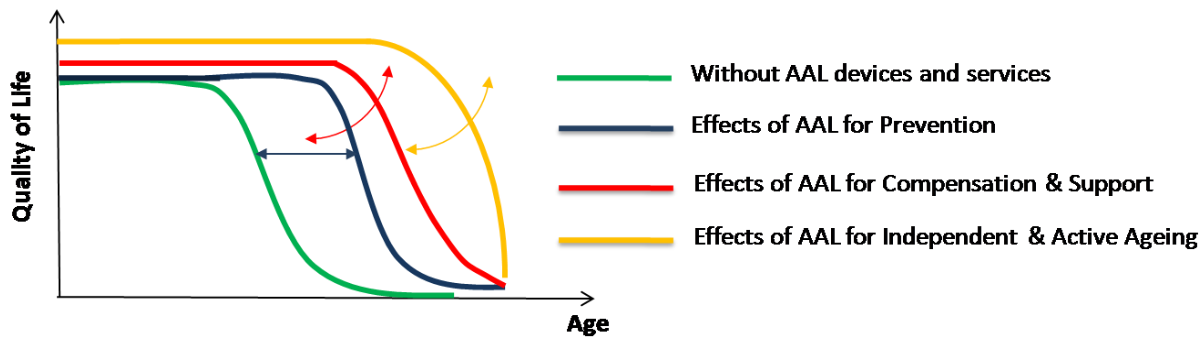

Figure 1. The model of QoL during ageing and the potential effects of technology solutions related to the prevention, the support and the independent living of aging society.(Moschetti,2014)

Eventually, the aim of this chapter is to describe how demographical and societal challenges related to the aging population and the increasing demand of nurse practitioners can be addressed and optimised by the integration of ICT and robotic technologies in a smart environment. In this manner social services can be enhanced, improving quality of life of the elderly population. Starting from literature evidences on how integrated solutions could support the active and independent living of aged care (sec. Introduction and Background), the authors analysed some criticisms related to the proposed technical solutions. Furthermore they show their concrete experiences of integrated solutions that overcome the criticisms described and the results achieved. In order to improve future researches in this topic, they conclude this work with recommendations based on the gathered experiences (sec. Solutions and Recommendations). Furthermore, the authors highlight the trend of development from stand-alone solutions to cloud computing architecture, describing the future research directions (sec. Future Research Directions).

BACKGROUND

As stated earlier, AAL technology can meet the elderlys' main needs improving QoL. So, some possible services and ICT solutions are shown in Table 1 and described in the following paragraphs.

Table 1. Relation between the needs of aging persons with technology solutions

Main Service Area	Possible services	Technical Solutions (Examples)
Social interaction	➢ Communication with friends and family ➢ Writing letters via speech control ➢ Encourage social interaction (gamefication) ➢ Contact with care staff, doctors etc.	(Sarkey, 2012; Furuta, 2012; Stiehl, 2005; Kanamori, 2002)
Information	➢ Documentaries and news via audio/video ➢ Speech controlled search function ➢ Information about places to visit/visited ➢ Reminding of tasks	(Shiotani, 2006; Cavallo, 2013) (Badii, 2009; Prakash, 2013)
Safety	➢ Monitoring risks and giving warning	(GiraffPlus, 2012; Mileo, 2008)

	➢ Make older users feel safe in and outdoor home ➢ Emergency calls ➢ Domestic environment monitoring	(TMSUK, 2014; Esposito, 2014)
Health	➢ Check health status ➢ Monitored rehabilitation with gesture control ➢ Documentation of care ➢ Communication with medical doctors ➢ Saving and updating patient profile	(Tóth, 2010; Matsusaka, 2009) (Jayawardena, 2010; Werner, 2012)
Leisure	➢ Games that encourage social interaction ➢ Games for physical and mental training ➢ Watch movies	(Keizer, 2014; Shamsuddin, 2012; Wada, 2006; NAO, 2014; Deterding, 2013)
Physical support	➢ Collection and distribution of laundry and garbage ➢ Check of stock amounts & date of expiry ➢ Order goods to refill stocks / online shopping ➢ Cleaning works ➢ Support caregivers lifting patients out of bed ➢ Support during walking or on stairs ➢ Transport of heavy objects ➢ Possibility to locate elderly when outside (e.g. family or care staffs) ➢ Navigation ➢ Providing a seat ➢ Bringing and moving goods inside house ➢ Open bottles and food packages ➢ Controlling devices in smart home ➢ Translating speech commands to control smart home devices	(Ferri, 2011; Secom, 2014; Mori, 2010; Cavallo, 2014a; Farahmand, 2006)
Mobility	➢ Support in personal mobility inside the house ➢ Public transportation	(Robosoft, 2014; Karlin, 2011; Bogue, 2009)

Social Interaction

Social participation and communication with friends, family, relatives and neighbours are important elderly needs. There are several studies which show that robots could be reliable companions for the elderly and useful tools to quantify and analyse interactions (Sarkey, 2012), indeed. Robots do not necessarily reduce human contact and socialisation; researchers have demonstrated that robots will address the social and the emotional needs of the elderly, including reducing depression, loneliness and isolation (Stiehl, 2005). For instance Huggable (Stieh, 2005) has got sensors to evaluate and quantify the affective component of touch during a normal interaction with a pet animal in order to capture eventual abnormal behaviour. Kanamory et al. (Kanamori, 2002) show improvements in aging persons who regularly interact with AIBO. Babyloid is conceived for robot baby-doll therapy; it encourages the patient to take on an active care-giving role, helping relieve symptoms of depression in the elderly (Furuta, 2012).

Information

Robots can facilitate the access to information such as documentaries and news via audio/video or information about places to visit/visited. For instance Wakamaru robot (Shiotani, 2006) and PaPeRo (Osada, 2006) are able to announce the weather report, read the news and communicate predictions (overall fortune, work fortune etc.) to share with elderly users; while guide robots (Arras, 2003)

(Yoshimi, 2006) are robots conceived for helping people in exhibition events. Through multi-modal interface they inform about the events, and guide people in the exhibition taking pictures of visitors and entertaining.
Furthermore older persons with cognitive disorders could have problems in remembering appointments, so robots could help users, acting as a physical support. ICT and robotic technologies should be able to provide a care environment that supports the day-time management; Companionable (Badii, 2009) and Astromobile (Cavallo, 2013) are able to help users and carers in reminding tasks.

Safety

Older adults who live alone in their own house need to feel safe and often desire to improve the sense of security and surveillance. They want to monitor the domestic environment and to be aware of risks. The GiraffPlus system made use of a telepresence robot, a smart environment and smart wearable sensors to monitor activities in the home using a network of sensors and alerting the user in case of necessity (GiraffPlus, 2014; Coradeschi, 2013). Mileo in (Mileo, 2008) described a smart home for critical situation recognition, posture analysis and user localisation. It was specifically designed to support caregivers in monitoring and providing health assistance to the elderly in their home. Mir-H combines robotics, internet and mobile technologies in order to provide security, remote monitoring, entertainment and home networking to users who require them. The robot will guard the home when the user is away and could inform him of an abnormal presence. Robiorior guards the home, and sends pictures and videos on a mobile phone alarming in case of necessity (TMSUK, 2014).

Health

Senior citizens often are worried about their health status and need to be in contact with their physician, therapist and other actors of the care chain. Sometimes these actors don't have much time to address all the requests guarantying high level of quality. These solutions could help in checking the health status, managing the documentation of care, communicating with carers and doctors, monitoring the home rehabilitation and having a healthy lifestyle. In particular, during the last years researchers have assisted to the rise of wearable devices to monitor health status and performance (MHN, 2014).
For instance András Tóth et al. (Tóth, 2010) introduced a smart environment for health services. Data from the wearable device was processed to implement fall detection service and activity monitoring service, analyse user fitness and monitor vital signs. Taizo is a robot to help senior citizens to lead the elderly in physical exercise (Matsusaka, 2009). Charlie can monitor vital signs (pulse, blood pressure) and provide mental stimulation by means of interacting games promoting active aging (Jayawardena, 2010). KSERA system is able to monitor the health and behaviour of an older person by using a sensor network and humanoid robot (Werner, 2012). Hospi-rimo allows them to talk with other residents and doctors in a care facility and enables families and friends who live far to virtually visit hospital inpatients or the elderly living alone (Panasonic, 2011).

Leisure

In literature there are several works which show the positive involvement of robots with elderly people for leisure activities and games. For instance, Wada et al. (Wada., 2006) analyse interaction between Paro and a group of the elderly. They found evidence that the level of social interaction among the elderly increased, while physiological indicators showed reduced stress levels. Robo-Doc 2 is a companion robot which is able to teach (encyclopaedia functionality) and entertain people playing chess and Chinese chess (Lin, 2006). FUWA has an LCD touchscreen which allows users to interact with educational or entertainment software (Zhang, 2008). Nao (NAO, 2014) is a humanoid robot; it can play soccer, sing and speak with the user. There are several works which show a positive attitude regarding this robot both for the elderly and children with autism (Shamsuddin, 2012; Keizer, 2014).
Another important aspect of technologies involved in leisure tasks is related to games for cognitive training which can provide short-term and long-term benefits to attenuate age-related cognitive decline in

older adults. In particular future researches are required to enhance efficacy of the intervention (Lampit, 2014; Deterding, 2013). Gamification is a recent key concept which involves the use of game techniques and mechanics to engage and motivate. Future predictions suggest that this interest will continue to grow, especially in the use of games to change individual behaviour (Schoech, 2013).

Physical support

Robots are designed to perform a single ADL[1] to promote users' autonomy managing their activity and their interactions. Older and disabled persons could have some difficulty in performing activities like feeding, grooming, bathing and housekeeping. For example, aging people with motor impairments have difficulty with picking up food and bringing it to the mouth; a feeding robot like My Spoon (Secom, 2014) or Bestic (Bestic, 2014) can support elderly users in eating. The intelligent Assistive Robotic Manipulator (Farahmand, 2006) is a robotic arm to assist disabled or older people with a severe handicap in their upper limbs. It can help to pick up and bring objects inside the house. The Assistant Robot -HAR is a home assistant humanoid robot which could help with household chores such as wiping the floor, washing and cleaning. *RIBA-2* (RIBA, 2014) can lift up or set down a human from or to a bed, wheelchair and toilet, using its very strong human-like arm and high-accuracy tactile sensors (Mori, 2010). Whereas Care-o-bot III is a multipurpose robot used to assist people in household; it can manipulate objects and make teleconferences.

In addition, robots could support older persons also outside of their home, collecting and distributing laundry and garbage. Dustcart (Ferri, 2011) is a wheeled autonomous robot for door-to-door garbage collection. DustCart is able to navigate in urban environments avoiding static and dynamic obstacles and to interact with human users.

Mobility

Another important aspect of AAL technology is that it could try to restore elderly mobility. This can allow an improvement of quality of life of the elderly. Robots for mobility assistance are classified into three main groups: Electric wheelchair with a navigation system like HLPR (Bostelman, 2007) and Smart Wheelchair. There are also mobile robots that support users in order to prevent mishaps and provide stability like ROAD (Carrera, 2011) which is a robot that carries the weight of the user in order to make up for the lack of physical strength of the caregiver.

Smart walkers can support elderly users in movement tasks; they are designed for people with movement residual capabilities (Robosoft, 2014). The exoskeleton robot can enhance users' movement and strength (Karlin, 2011).

Public transports are fundamental to independent living of older people. These systems must be accessible and easy to use in different places like city centres, industrial or academic campuses, public parks or airports. For instance RobuCAB is an electrical cyber car allowing the transportation of four persons in an automated way. The vehicle works then either in a standalone vehicle or in a fleet vehicle managed by a supervisor. Another autonomous electric vehicle is robuRide that can transport people from station to station using pre-learnt routes, either on a shuttle mode or on an on-demand mode (Robosoft, 2014).

LESSION LEARNT

However, according to the literature on technology to promote ageing well in place, some crucial barriers come out. First, ICT and robotics solutions often are developed without deeply knowing the end-users' needs and what are the social and infrastructural conditions in which such technology should work. Second, the design and functionalities of technology are thought up regardless of usability criteria that are influenced by users' technology experiences. Third, usually, one user's need is met by one ICT and robotic solution and often the developed system is not able to adapt itself efficiently and fast to users' or

[1] ADL: Activity of Daily Living

environmental changed conditions. Fourth, the technology solutions are not tested with real end-users in order to assess the technology acceptance.
Therefore, the RoboTown Living Lab (LL) takes on these challenges in many EU and local projects (DustBot (Ferri, 2011), AstroMobile (Cavallo, 2014b), RITA (Esposito, 2014), Robot-Era (Cavallo, 2012)), which contribute to implement RoboTown's services and RoboTown LL infrastructure, in order to overcome the shown barriers.
RoboTown LL of Scuola Superiore Sant'Anna is located in Peccioli (Tuscany, Italy) and includes DomoCasaLab and Peccioli's town centre with its municipality; about 5,000 people live in Peccioli, with a large percentage of elderly people (25%). The actors involved in the RoboTown LL ecosystem are Scuola Superiore Sant'Anna, SMEs (RoboTech, TechnoDeal) and the Territory of Alta Valdera. In this sense, RoboTown LL represents an opportunity to enhance the cross-fertilisation between academy and industry in order to overcome the gap between service robotics technologies and the current market. Since 1995 RoboTown LL plays a central and important role by creating a bridge between technological communities, local administrations and public institutions.
The aim of RoboTown LL is to overcome the barrier related to the flexibility, modularity and continuity of services. In other words, the services developed have to be functional in heterogeneous environments, such as private homes or public areas. In this context researches at RoboTown LL defined robot 3D services (Cavallo, 2012) which implement multiple-users and multiple-robots in multiple-environments (sec 3). With this new paradigm there is the transition from *(one user-one robot)* to *(n user-one robot)* where a single robotic platform can provide services to different users (for instance a robot which is able to move in a condominium environment); this concept will be described in the following sections.
Furthermore in order to prevent users from changing their behaviour to accept ICT and robotic solutions; at RoboTown LL a User Centre Design (UCD) (ISO 9241) approach is applied. This approach consists of different aspects allowing the development of wireless technologies, and home comfort and robotics services solutions for the elderly population are sustained by a multidisciplinary team in which technology developers, designers and end-user representatives collaborate. The shown barriers were ridden over involving users in all design phases:

1. Analysis phase (sec 4) – at the beginning users are involved to know full well their needs and attitude towards technology in order to develop useful ICT and robotics solutions
2. Design phase (sec 5) – at the middle users are involved to provide feedback on the technology design so that it would be accessible. The accessibility also makes technology more acceptable and usable by people in a wide range of situations
3. Evaluation phase (sec 6) – at the end, users are involved in active experimentation in order to validate the usability and acceptability of the developed ICT and robotic solutions

IMPLEMENTATION

The AAL technologies designed and implemented at RoboTown LL provide assistance and healthcare support, transportation of goods and persons enhancing social inclusion and independent living of senior citizens. The solutions developed are modular, flexible and customisable and are able to help and support the daily life of users everywhere and at every time, overcoming spatial barriers. Based on past and on-going projects, infrastructure, robots and service were implemented in order to cooperate and operate in indoor and outdoor environments (3D service paradigm).

The RoboTown LL is composed of three different environments: the indoor, the condominium and the outdoor environment.

1. The *indoor environment* is composed by the DomoCasaLab (Figure 2.A), which reproduces a fully furnished apartment of 200 mq with a living room, a kitchen, a bathroom and two bedrooms.

2. The *condominium area* is composed by a main entrance of the building, a hall at the ground floor, a corridor at the first floor and an automated elevator remotely controlled. The elevator allows to perform the multi-floor navigation (Figure 2.B).
3. The *outdoor environment* is around the business incubator and the area is covered by a Wi-Fi network. Also a video surveillance system is installed in order to prevent failures or damages (Figure 2.C).

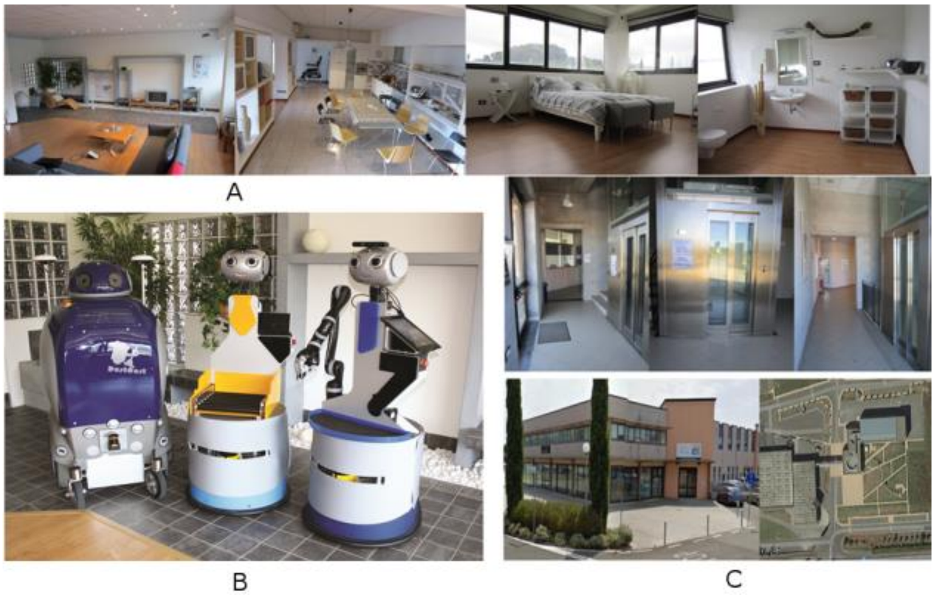

Figure 2. The infrastructure and the companion robots developed at RoboTown LL. (A) the DomoCasaLab (B) the three robotic platforms: the outdoor, the condominium and the domestic one, respectively (C) the condominium environment with the elevator, on the top, and the outdoor environment, on the bottom.

In these environments AAL technologies are well integrated to provide adequate and continuous services (see Figure 3).

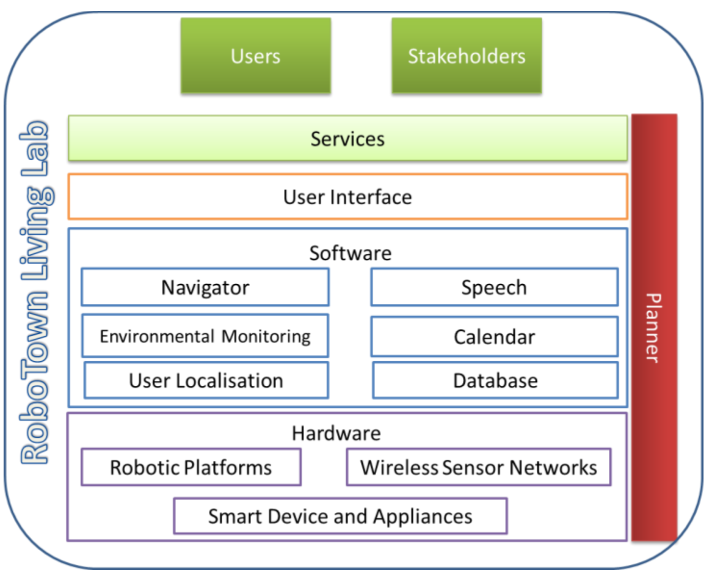

Figure 3. System architecture: the hardware, the software, the planner and the user interface

Hardware

Robotic Platforms – (Figure 2.B) One of the aims of RoboTown LL is spreading out a set of integrated AAL services from home to town. For this reason, the use of suitable robotic platforms, able to act in domestic, condominium and outdoor environments, is essential. The foreseen *outdoor robot* is developed during the Robot-Era Project. This platform is an autonomous mobile robot designed to transport objects in an urban environment such as escorting senior citizens, performing door-to-door garbage collection and providing shopping and drug delivery services. A *condominium robot* is designed to act as a concierge and to perform logistics and goods transportation in the building. It is able to autonomously move inside the building and take the elevator. It is equipped with a set of rollers to perform tasks of exchanging objects with the outdoor robot. The *domestic robot* is a mobile platform equipped with a touch screen tablet, voice recognition and synthesis, a manipulator and a handle to physically support elderly people. The condominium and the domestic robot have coloured Light Emitted Diodes (LED) in the eyes for facilitated and immediate interaction with the user and inertial sensors in the head. They are also endowed with localisation and obstacle avoidance sensors for autonomously moving in the environment and a Wi-Fi module to communicate with other agents.

Wireless Sensor Network – The DomoCasaLab is equipped with four different wireless sensor networks (WSNs): User Localisation Network, Environmental Sensor Network, Body Sensor Network and an indoor video surveillance system, in order to monitor the user activity supporting the user in the managing of the house. The environmental WSN based on ZigBee technology is implemented integrating environmental sensors (temperature, humidity, light) with user presence, water/gas leak and door/window opening. The Body WSN is used to measure physiological parameters as heart rate, respiration rate, temperature, activity and posture. As regards WSN for indoor and outdoor localisation a wearable module was developed. The system was composed by an inertial sensor to monitor motor activity, a GPS receiver and GSM/GPRS module for outdoor localisation, a ZigBee module for indoor localisation and the GPS and ZigBee antennas. The system was able to switch automatically from GPS (outdoor open space) to ZigBee module (indoor environment). The capability of help request was integrated in the same device.

Smart Appliances – Sensors are integrated in commercial appliances and furniture. For example, smart-plugs will collect data on the energy expenditure, and barcode reads and load cells will provide data to estimate the quantity of food in the smart fridge. The status of appliances like the oven or bathroom fixtures could be monitored.

Software

Navigator – The Navigator module is implemented to control the autonomous movement of the robot and to acquire information from sensors installed on the robot, such as odometry and laser. Navigator communicates with the robot actuators and sensors by means of the Player framework.

Environmental Monitoring – An environmental WSN monitors the home status by using several types of sensors (a switch on the entrance door, PIR, light, humidity, temperature and water leak sensors). Data acquired from this WSN are collected and processed by this software module. This software monitors the home status and alerts users and carers in the case of critical situations.

User Localisation – The system is able to locate users in need of robot support in the continuous care service. A localisation software acquires data from heterogeneous commercial and ad hoc sensors, to estimate the position of the user. A sensor fusion approach is investigated to locate people in a robust and scalable manner. The accuracy and cost of the indoor localisation service will depend on the typology and number of the installed sensors. In the case of a sensor fault, the user position is estimated by fusing data from the remaining ones, improving the reliability and robustness of the service.

Speech – The speech module represents the natural language interface between the end-user and the robot by means of appropriate commercial tools of speech recognition and vocal synthesis.

Calendar – A calendar tool is integrated into the system, and provides a service to carers and users. For instance it could be used for medication and care management. In this way, users and carers are allowed to schedule therapies and medical visits on the calendar. The system automatically addresses a robotic reminding service at the scheduled time, to remind the user about appointments or medication. The appointment could be added by means of custom web application or Google Calendar.
Database – The database is able to storage data, to retain the data and optimise the searching procedures. It contains the WSNs outputs and the environment maps for the user localisation procedures. Furthermore, the database stores the maps for the robot navigation in unknown environments.

Planner

The heterogeneity of the components involved in the system requires a form of sophisticated reasoning: the tasks typically required can be accomplished in different ways depending on the specific state of the environment; they are in general dynamic, which is to say that the human user can post them anytime, also implying concurrency between multiple goals; and other requirements can even be generated by the system itself monitoring the state of the system (e.g., a gas sensor could trigger the intervention of a robot to notify the user). Furthermore, a task execution often requires a set of interconnected (and heterogeneous) actions carried out by a multi-robot system in which the access to shared resources (e.g., a condominium robot supporting the activities related to multiple apartments) must be carefully managed.
This kind of set is called ‘plan’ and it was managed implementing a dedicated planner (Di Rocco M., 2013).

User Interface

The user can exploit RoboTown services by means of multimodal interface (touch-screen, speech); in addition custom interfaces have been developed in order to provide more useful service. Web portals are able to manage different services (garbage, communication, shopping, reminding). Furthermore another web portal provides home monitoring (mean light, humidity and temperature and entrance door status). It is connected directly to the database, and the access is restricted to authorised people only. In addition, the localisation web page reports the room where the users are located.

ANALYSIS PHASE

‘Incomplete understanding of user needs is one of the major sources of system failure’ (ISO 9241); in fact technology is too often oriented to a young technical target and the ICT solutions designed for elderly people and the other involved stakeholders highlight the lack of a specific analysis of their needs and attitude towards technology.
The RITA Project started from an accurate overview of the situation of elderly assistance on the territory thanks to the support of public and private socio-medical organisations working with elderly people. In this study more than 200 elderly people were interviewed about their quality of life and needs, as well as about the services received by social-medical organisations; also 70 among formal and informal caregivers expressed their opinions about the quality of services (Figure 4).
Starting from ADL (Katz, 1963) and IADL (Lawton, 1970) scales, WHOQOL-BREF and WHOQOL–OLD (Power, 2005), two investigation questionnaires were designed using both a five-point Likert scale, for collecting easily information and comparing answers, and also open-ended questions allowing subjects to express freely their opinions.
The acquired data showed that the 66.5% of participants were alone or together with his/her old partner and had contact with their descendant family mainly via phone calls and one/two visits per week. Furthermore about 80% of them had some health problems and followed at least a medical therapy but they met their general doctor one or two times per month. Concerning the daily activities evaluation, the majority of participants were self-sufficient, however almost all needed help to perform some of these tasks.

In addition, the health problems and the social isolation risk, due to motor diseases or depression, were the main factors that influenced the perceived quality of life.

Furthermore older people should be able to access ICT and robotic solutions quickly and easily; for this reason the elderlys' attitude towards technology was investigated. The results showed that all involved people used without problems the TV and the devices connected to it (VHS recorder and DVD player) and the everyday appliances such as washing machine, vacuum cleaner, dishwasher etc. It should be noted that many older adults used the MP3 players (40%) and satellite navigation system (50%) and all participants had a mobile phone and used it without any problems. In addition many interviewed elderly people were able to use a computer and most of them used internet for entertainment and information. Finally the encouraging data was that the involved old persons reported willingness to learn of new technology use in order to be in step with the times.

Investigating the caregivers' point of view about the introduction of technologies in assistance services for the elderly, 91% of formal caregivers believed that these new types of interventions could increase the quality of service. Furthermore technology could improve the security of the elderly and could consequently have positive effects on elderly quality of life respectively for 82% and 77% of the sample.

Figure 4. Some focus groups with elderly people and caregivers in order to understand user needs

In order to meet the elderlys' and caregivers' needs identified during the analysis, the following services were implemented:

- *Indoor and outdoor localisation*: The developed system could help caregivers to know always where old persons were, especially during their absence. Furthermore the wearable module allowed elderly people that have feelings of vulnerability and insecurity to go out for their activities in safety because they could be localised with high precision in case of need. The system is composed of an inertial sensor, GPS receiver for outdoor localisation and ZigBee module for indoor localisation (Bonaccorsi, 2014). The caregiver could localise the user by means of user-friendly interface.
- *Help request:* In this way elderly people could maintain their autonomy and independence and the caregivers could be dismissed from permanent assistance because in case of need an old user could activate a help request and could be localised in both indoor and outdoor environments thanks to a wearable module. In particular, this module sends a SMS on the caregiver's phone when the user needs help. The sending process may be automatically under certain conditions (i.e. user fallen). The same wearable device is able to perform the '*Indoor and outdoor localisation'* and '*Help request',* improving the usability.
- *Domestic environment monitoring:* Sensor network allowed elderly people to live at home in security because unexpected environmental changes were detected and alert requests were promptly sent to the caregiver. These technologies together with the localisation module allowed to estimate elderly motor and static activities (for example, time in front of TV) and recognise some activities as sleeping or napping. This information could be useful for caregivers to plan activities to maintain senior users active from the motor and social points of view.

- *General health status monitoring:* Thanks to a wearable monitoring device, the main physiological parameters could be monitored, stored and remotely analysed by a medical doctor. In this way elderly people could receive more attention about their health by clinicians increasing their safe feeling. Also one formal caregiver could monitor more old persons at the same time improving the quality of service and reducing the costs.
- *Reminder:* Technology can support elderly people in reminding tasks. The user, or the family members, can set up commitments and appointments by means of Google Calendar or a specific web portal. At a proper time, the system, through the robot, alerts the user; the robot reaches the user acting as a physical reminder by means of physical presence, voice synthesis and visual reminder on the tablet. Furthermore, it can bring and transport objects (i.e. pills, or water bottle) by means of robotic arm supporting elderly persons with physical disabilities.
- *Indoor and Outdoor Mobility:* Robots are physical agents with embodiment characteristics, so they can empower the personal mobility of senior citizens. The domestic robot can help users in personal transferring inside the house, getting up from the chair or the bed by means of an appropriate handle in the back. In order to promote the ageing social inclusion, also the outdoor robot presents a handle with a joystick, so it can provide physical support during the outdoor walking.
- *Communication:* In this service elderly persons improve social inclusion, having video conferences with family and friends. By means of robot the user can do phone calls and see far friends and family. Robots' multi-modal interfaces can facilitate the use of the services from the users' points of view.
- *Shopping/Garbage Collection:* These services provide a complete means of delivering groceries from the shop to the user's apartment and garbage collection from the apartment to the collection point. Using these services, the user can receive continuous support in daily activities by means of a 3D-service. The services start with a user's request through a voice command using a wearable wireless microphone or using the interface running on the robot tablet.

DESIGN PHASE

After the Analysis Phase, the users were involved in the Design Phase. In the ASTROMOBILE Project some elderly volunteers were recruited to be involved in the analysis of design criteria and in particular the study investigated:

- Interfaces to facilitate the interaction between elderly persons and robot
    - types of interfaces (speech recognition and vocal synthesis, visual interface, touchscreen, buttons and screen, remote controller etc.)
    - redundancy
    - feedback (coloured lights)
- Appearance of ASTRO robot to be perceived safe, friendly and acceptable by senior citizens
    - shape (human-like, unhuman-like)
    - dimensions
    - colours
    - materials

Then a focus group with eleven old persons living in the Peccioli area (Pisa, Italy) was carried out to study what seniors think about the robotic assistant, how they configure it in order to perceive it usable and acceptable. To collect this information an ad-hoc questionnaire was conceived and used during the focus group; this tool was made of both multiple-choice questions and free response questions in order to compare and quantify elderly opinions but at the same time to collect their free motivations.

From the survey with seniors it emerged that most participants chose the vocal interface and the remote controller because for them speaking is the most natural way for communicating so they would like that the robot could understand their vocal commands and also reply to them with vocal messages. Furthermore about the remote controller seniors know well about using a TV remote controller so they

suggested using a similar tool to control also the robot. In addition elderly persons appreciated the idea to use redundant interfaces (i.e. both visual and vocal messages) because they are free to choose how to interact with the robot according to the situation and to be sure of having comprehended robot feedback.
Concerning the ASTRO robot appearance most of the elderly pointed out that a human-like shape would be perceived as more friendly and the robot size should be smaller than a human one in order for the user to perceive the control on it. Furthermore about the robot colours, the most voted ones are blue and grey because they are two soft colours that don't evoke anxiety and they should coordinate well in a domestic environment. Then during the focus group elderly subjects touched different kinds of materials (plastic, rubber, metal) having different consistencies (soft, rigid) and textures (smooth, rough). After asking them to choose the material for the robot cover, most of the elderly preferred the combination of rigid material with spongy areas.
Results obtained from these surveys were used to address the design of the ASTRO robot's appearance and the final version of the robot had a human-like shape with a head having some human-like features (stylised eyes and mouth) (Figure 5). Furthermore the ASTRO cover was made of ABS, a rigid thermoplastic material, having some spongy trimmings on robot trunk sides and on the head at the level of ears. Finally the ASTRO cover was coloured grey and the spongy trimmings were blue with two possible versions (jeans and patterned). Concerning the human-robot interaction, ASTRO was designed to support both the touch screen for GUI and a recognition software for the vocal interaction. Furthermore ASTRO was developed to provide coloured lights feedback related to the task at the level of ASTRO's eyes.

Figure 5 Preliminary studies of initial concepts and final version of ASTRO robot

EVALUATION PHASE

After designing and developing the ICT and robotic solutions, elderly volunteers were invited to DomoCasaLab to interact with the robots and other devices in order to evaluate the technical effectiveness and acceptability of the proposed services. The aim of each robotic project is to demonstrate the feasibility and the effectiveness of robotic services for the user target for which these services are developed. This purpose could be achieved with intensive experimentations, involving all stakeholders in realistic or real environments. The final objective is to investigate the acceptability and usability of the system in order to reduce the time-to-market.
The experimentation consists of three phases:

1. *Pre-test phase* in which the stakeholders are recruited according to the inclusion criteria and general socio-demographic data are acquired
2. *Test phase* in which the enrolled stakeholder tests the robotic service
3. *Evaluation phase* in which the acceptability and usability feedbacks from the user are collected

Pre-test phase

One of the most important issues regarding a successful experimental loop is an adequate selection of test participants. The recruitment phase is crucial because the reliability of the final results depends on the enrollment of a suitable sample focussed on the project aims. In our experience more than fifty elderly people, aged over 65 years old, without severe cognitive impairment, were recruited. After the subjects' enrollment, the socio-demographic data needed to be acquired in order to have a description of the sample.

Test phase

Before the experimentation, the consciousness of technological possibilities is often a little low, demonstrating that end users are unaware of the potential of technology to help them in daily lives. For this reason, a training phase is indispensable either for elderly people and caregivers.

Before starting, both in RITA and Robot-Era experimentation, an elucidative video about the developed technology potentiality was shown to test-users in order to increase users' attitude towards it. Furthermore the researchers dispelled users' doubts so elderly people and caregivers participated in a well-aware way.

After the training phase there are many modalities to conduct experimentation with real end-users.

In the RITA Project two focus groups were conducted, one with elderly people and one with formal caregivers, for testing RITA services and ICT system (see Figure 6). The focus group is a technique for social research based on discussion among a small group of people invited by one or more moderators to talk deeply about the topic under investigation. The involved subjects define their position on the issue, confronting each other. The drawback is that people can influence each other, but the researcher can limit this problem.

On the other hand in Robot-Era projects elderly persons were invited to interact with robots in a realistic condition. The experimental environment was set as real as possible in order for the user to interact with the robotic system, perceiving the usefulness as in real life. The researcher was present during the experimentation for security issue.

The future direction will consist of realising a long-term experimentation involving the end-users in their environments to test the ICT and robotic solutions in real conditions. In this experimental modality the researcher will be not present and the test-user cannot be influenced.

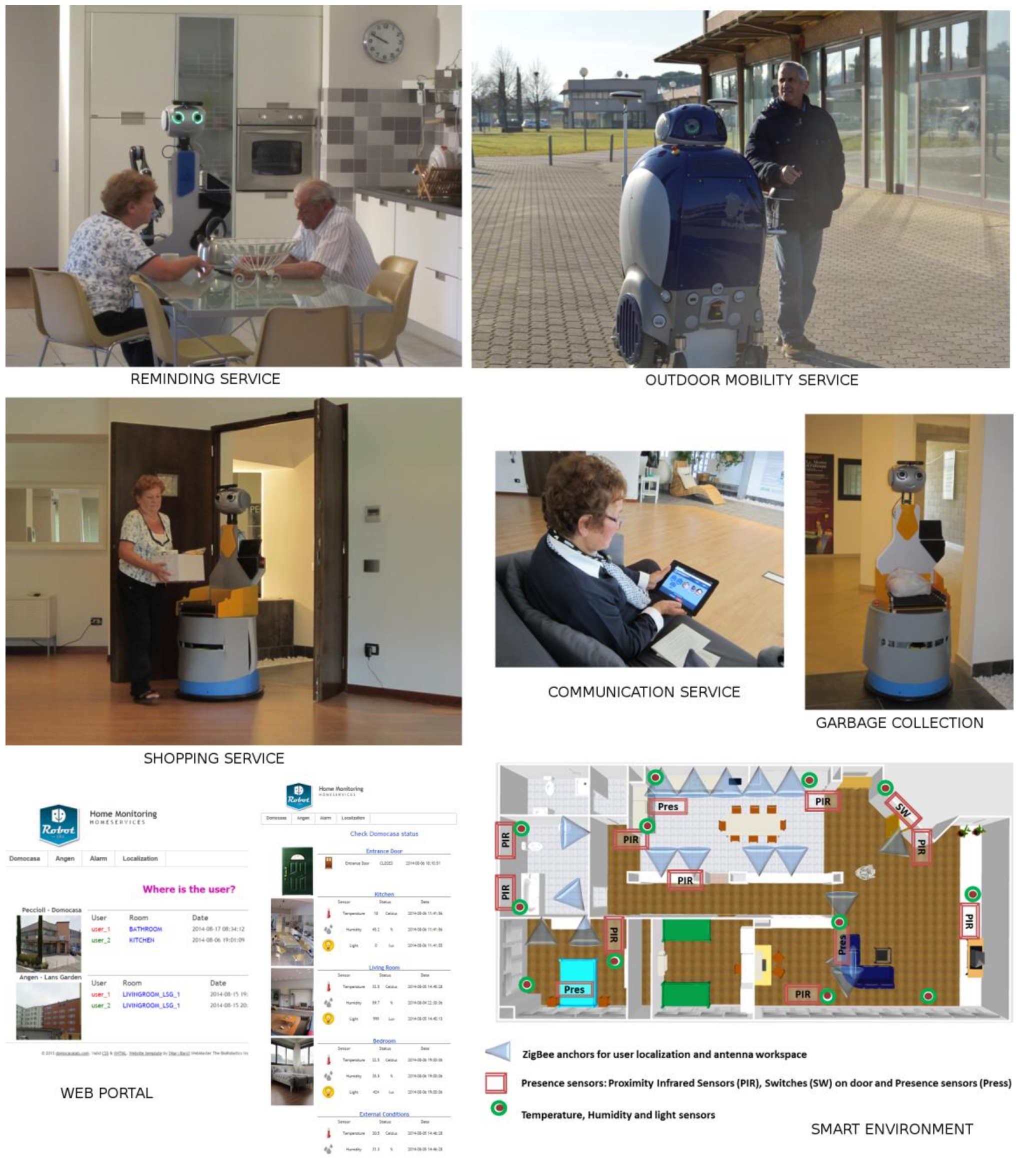

Figure 6. Examples of services implemented at the RoboTown Living Lab. At the bottom are shown on the left the web portal for the home monitoring and the user localisation, and on the right the sensors in the DomoCasaLab.

Evaluation phase

In this phase the usability and acceptability of the system needed to be investigated in order the design addresses the whole user experience.

Usability refers to the 'extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use' (ISO 9241). It can be evaluated with many tools such as 'Thinking Aloud method' or 'Systems Usability Scale'. In the Thinking Aloud method the participants are urged to describe what they do and think vocally during the accomplishment of tasks. This measure is particularly used with test and analysing methods (Ericsson, 1993). The "Thinking Aloud method" allows the researcher to investigate in detail the overall user experience because people express their feelings, thoughts and scepticisms directly when using the system. By using only interviews and questionnaires the data which will be produced spontaneously (like cursing and swearing) will be lost for documentation and for the data analysis. Furthermore the Systems Usability Scale (SUS) (Brooke, 1996) is a simple and not highly detailed evaluation method that uses a standardised form with ten questions to assess the product's usability. The noted benefits of using SUS include that (1) it is a very easy scale to administer to participants, (2) it can be used on small sample sizes with reliable results and (3) it is valid because it can effectively differentiate between usable and unusable systems.

Acceptability is defined as 'the demonstrable willingness within a user group to employ technology for the tasks it is designed to support' (Dillon, 2001). Technology has become an important part of our everyday lives. Human-computer studies and human-robot studies focus on the interaction between humans and technological objects. In general, technology acceptance models are used to analyse the complex relationships between different variables and the acceptance of technological products. In studies on robot acceptance, this has some drawbacks because robots are more complex than other technological devices such as computers; in fact their acceptance depends on their shape, functions and capabilities. The Technology Acceptance Model (TAM) (Davis., 1989) is the most prominent concept. It was developed to understand expectations about information technology usage and comprises two main variables that have an impact on acceptance: perceived usefulness and perceived ease of use. Nevertheless, the TAM does not take socio-demographic factors into account. Another approach is the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, 2003), which suggests four key constructs (performance expectancy, effort expectancy, social influence and facilitating conditions) as direct determinants of usage intention and behaviour. This concept takes into account socio-demographic factors (gender, age) and individual factors (experience, voluntariness of use), which are deemed to be influenced by the four key constructs.

In the RITA Project the users' feedback was collected through an ad-hoc questionnaire based on a five-point Likert scale (scores on 'negative' statements like the ones on Anxiety had reverse scores). From the survey with seniors it emerged that 72.55% of them had the intention to use the system over a longer period in time, if this technology would be economically accessible. In confirmation of these data, most elderly participants (83.62%) perceived the proposal system very useful because they believed that using the RITA services would enhance their self-assurance (90.20%) and quality of life (47.06%). Furthermore the usability was well estimated by 67.35% of the older volunteers who didn't feel anxiety during the test session.

The results obtained from the surveys with formal caregivers were very positive as you can see in Figure 7. Furthermore the technology doesn't hurt the relationships between caregiver and assisted person according to participants' answers (89%), but all caregivers thought that the use of showed technology and services could improve the quality of the provided socio-medical services.

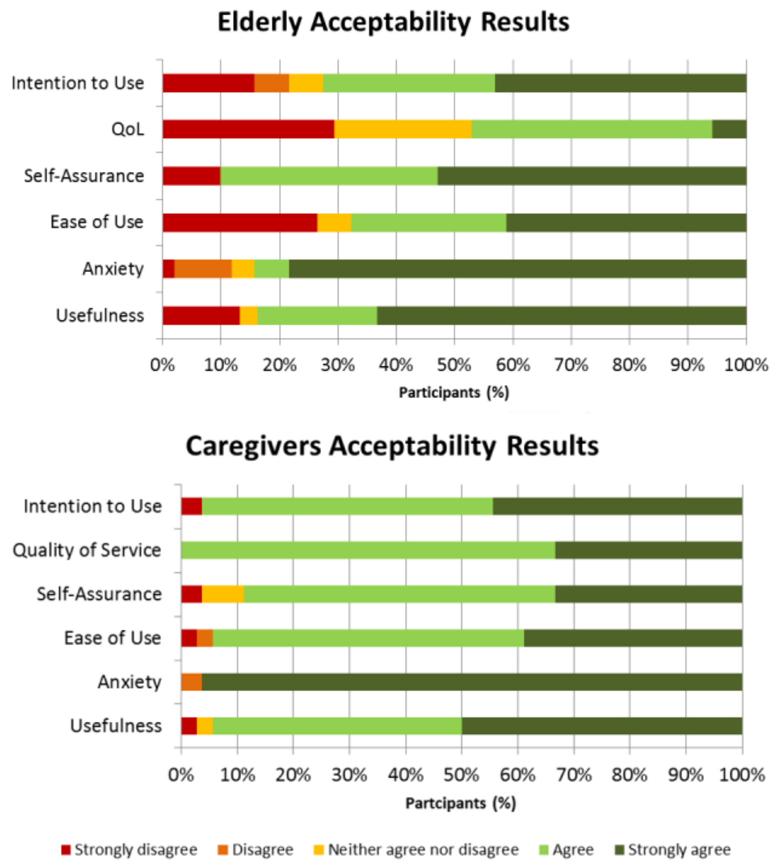

Figure 7. The acceptability results gained in the RITA Project. On the top there are the results regarding the elderly persons, while on the bottom there are the results regarding the caregivers' part.

In Robot-Era projects the SUS was used to compare the usability of all services in an efficient and validated way. Regarding the acceptance, an ad-hoc questionnaire, based on the UTAUT core constructs, was developed. The outcomes of the surveys were elaborated in order to get a Usability and Acceptance Score range from 0 to 100 and the interpretation of the score is (McLellan, 2012):

- 0-64 points: not usable / acceptable
- 65-84 points: usable / acceptable
- 85-100 points: excellent

The main results on Usability and Acceptability of each Robot-Era service are reported in Figure 8. In general the Robot-Era services were judged strongly usable, as shown by the number of scores related to the 'Excellent' range (green bar). In particular according to the elderlys' feedback, the Robot-Era services were easy to use and the actions performed by the robots were well integrated. However the 'Shopping and Drug delivery' and the 'Reminder' services were not usable for some users, because these tasks were performed using a GUI runnable on a tablet and some of the elderly were not confident with this device.
The questionnaire on the acceptability of the Robot-Era Services was elaborated considering its different parts, Attitude, Acceptability attributes, Human-Robot interaction, Graphical interface, Vocal interface and Effect on the Quality of Life, in order to get a unique score. The main results of the analysis are reported in Figure 8 and as shown, most of the older persons participating in the experiments provided positive judgments about the acceptability of the services and the mean values of the score were in the range 'Excellent' (green bar).

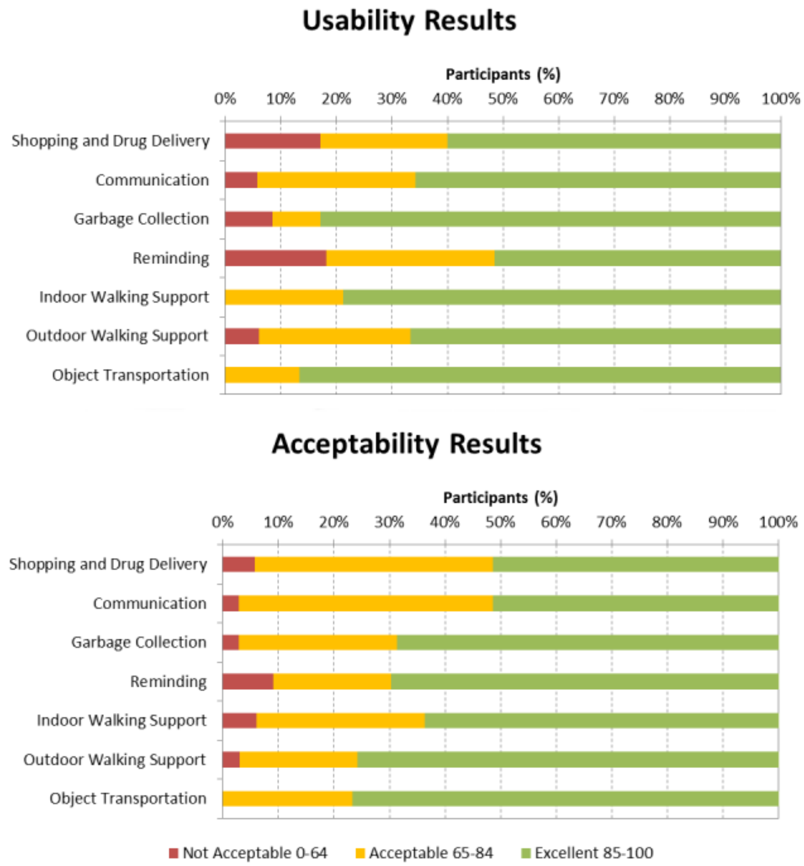

Figure 8. The Usability (top) and Acceptability (bottom) results gained during Robot-Era experimentation

The researchers at RoboTown LL learned three lessons from the experimentation conducted with end-users. First, elderly people prefer to interact with robotic systems using a vocal interface because they perceive it more natural and easier to use. However observing the conducted tests we can assert that elderly persons learned quickly to use GUI on a tablet, if the interface was developed according end-users' attitude and experience. Second, the obstructiveness of the ICT and robotic solutions should be minimised to reduce the impact on the user's environments and lifestyle in order to improve the usability and acceptability. In fact if the technology is integrated in the environment, it is perceived more usable and it doesn't evoke anxiety in the elderly persons. Third, the intention to use a new technology is strongly related to the perceived usefulness, so in order to improve the acceptability elderly people should follow a basic training to understand the technological functionalities.

SOLUTIONS AND RECOMMENDATIONS

The experience described in this chapter demonstrated that AAL technologies are nowadays feasible and effective and can actively be used in assisting senior citizens in their homes. It is evident from RoboTown LL experiences that these technological challenges require an interdisciplinary approach, including expertise from the domain of medical science, robotics, engineering and computer science but also expertise from the domain of architecture, design, psychology, law and ethics. Furthermore robotics and ICT solutions should be distributed and pervasive in order to support the entire population from home to hospital, from residential facilities to smart quartiers. These solutions should be integrated in the design of the environment, in order to reach a high level of acceptability and usability for the users.

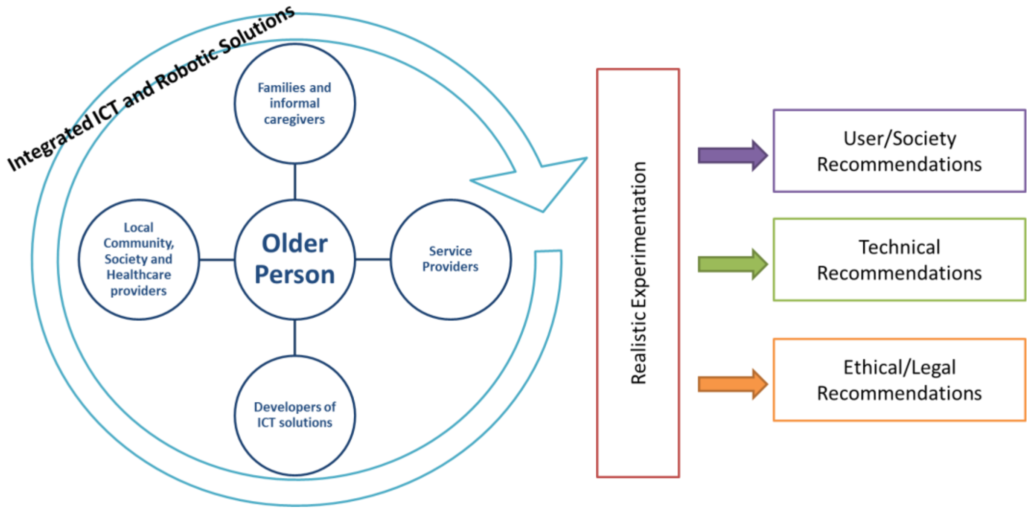

Figure 9. Recommendations come from the experimentation with real users at the RoboTown Living Lab

It is worth mentioning that from the real experimentation, with real users in a realistic environment, some general recommendations concerning society/users, technical and legal/ethical issues come out (Figure 9). In particular, analysing the system from the point of view of end-users and stakeholders, future usable robotics and ICT solutions should have:

1. Society centred design: since the robotics solutions should be used by users as an active support of daily living, they should be designed, developed and implemented for the society and around the society, in a society centred design approach. The future technology should pass from user centred design to society centred design, where the design phase should be taken into account and also the society's need. All the projects described in the previous sections were developed including users in all the phases, from the analysis of end-users' needs to the evaluation of the prototypal system in order to gather useful feedback and comments.
2. Stakeholder readiness: since the integrated solution should be usable also from society's point of view, it is also important to take into account the time-to-market. That is the degree to which the people and systems are ready to adopt and diffuse the technology in a reasonable time frame. This issue is strictly related to the gap between the research and the commercialisation of a product.
3. Low cost: since the robotics are intended to be personal, the cost should be compatible with users' economic possibility, in order to allow a large service utilisation. The reduction cost of robotic solutions is a result of a cost-benefit analysis: on one hand, the robotic system is expensive because of the high technology used; on the other hand it could reduce the cost of hospitalisation. In this context a new model of business built on cloud robotics solutions could have the potentiality to offer a new generation of personal robots.
4. Customisability, flexibility and modularity: users' needs are different and change over time. As a consequence, it is important to provide a modular service which could adapt to user needs and capabilities which could change.
5. Robustness, dependability, safety and security: since the robotic system should interact with weak and older persons, it must be safe and reliable.
6. Autonomy: the robotic system should be able to move autonomously and make decisions according to need of users, and should recognise mistakes committed by users or itself and self-correct, when necessary. The robot should also provide for emergency situations and to act independently to avoid them.

7. Training: the realistic test with real users also demonstrated that the introduction of AAL technologies in the public and private system of social care services was not easy because of the mistrust of caregivers regarding these new strategies of care based on technologies that will change their professional role. Particularly, moving forward in bringing AAL technologies to the home required dialogue between academia, service providers and patients and their families. For this reason, the training activities for caregivers focussed on the existence of AAL technologies, and their use was fundamental to demonstrate to them that AAL technologies can help them in their work without reducing their importance and role.

From a more technical point of view, the experiences acquired during the experimentations described before enhanced critical issues that, in the authors' vision, should be considered as a starting point for future works.

The key aspect of an autonomous and pervasive system is the integration among its own elements and with third-part solutions; a robust and effective integration should have the following characteristics:

1. Dependability: one of the most critical problems of a monolithic system (as a stand-alone robot) is its dependability. Using a distributed approach, a single problem with an agent of the system would not compromise the whole status. A dependability test should be performed improving safety and repeatability.
2. Cloud computing resources: a future integrated system should be able to be integrated also with cloud resources in order to increment the quality of service, the storage and the computational capabilities. In this way also technical solutions could be proposed in a pay-per-use modality, decrementing the total cost.
3. Intra-communication: all agents should have the possibility to communicate to each other. In this way, a simple and local process can be performed with direct communication between involved agents, without the necessity of a global management performed by the planner.
4. Extra-communication and modularity: in order to guarantee future development of the system, the interface between the system and a possible external application has to be stable and well-defined. Furthermore, the system has to be modular: in this way, further specialised modules can be easily defined, developed and integrated. In our experience, the modular approach allowed to easily integrate the elevator in the Robot-Era system. In conclusion, a complete and easily understandable interface and a well-organised modularity are the bases for further development of the system.
5. Multimodal and natural interface: generally the users have little or no experience with computers or other technologies. So, robotic applications need easy interfaces in order to allow natural interaction with the agents. As a consequence natural and untraditional interfaces should be taken into account. Following this direction, specific research has been performed implementing natural language based interfaces and developing an intuitive dialogue manager. Future research will focus on gesture recognition.
6. Integration with mobile technology: since mobile technology has become an important part of our daily life, a robotics solution should be integrated with it in order to enhance the acceptability and usability level.
7. Integration with social networks: since social networks are becoming more common in our daily life, technological solutions should be integrated with them, avoiding the multiplication of several user interfaces improving the usability.

Finally, several ethical implications must be taken into account before designing and adopting new solutions. These considerations generate a set of constraints with respect to the design and conditions of adoption of a robotic system collected in the European project Senior (SENIOR, 2014) and that were summarised in (Cavallo, 2012) as the following:

1. Adoption of the system must respect the user's freedom of choice: it must not be imposed, but proposed. It should be presented as an alternative to or an improvement over the existing service provided to the user, and if the system provides a novel service, care must be taken not to present such service as an obligation, but as a choice.

2. The system must reinforce personal autonomy: functional performance of a robotic system must not become an incentive for the user to become dependent upon the system.
3. The system must safeguard dignity and self-esteem: functional performance of a system should not come at the expense of the user's sense of self-worth and dignity.
4. The system must emphasise user safety: while a priori obvious, this consideration touches an interesting ethical question insofar as it may require the designers of a given system to voluntarily limit the control given to the user over that system. The line separating a valid security measure to an ethically reprehensible hindrance to user freedom may thus become difficult to identify in some cases.
5. Policy relevance: the commercialisation of a specific device is strictly correlated with the degree to which use of a particular technology aligns with currently adopted or emerging policies. On the other side, the use of a specific integrated technology solution can inspire positive change to long-term care system policies.

FUTURE RESEARCH DIRECTIONS

In the context of the background depicted, ICT systems and robotics services have been developed in order to provide a valid solution to support the independence of elderly people and improve a sustainable healthcare system. Analysing the current state of the art, it is possible to recognise a trend over the use of ICT and robotic solutions: the first solutions were focussed on the creation of a stand-alone solution, both a robot or a sensor network or ICT technology. Thereafter, these solutions have been merged and, at the same time, the intelligence of the system has been moved from a central actor to a more distributed architecture. The current direction of development is going towards a cloud design, where resources, software and information are shared over a network infrastructure.

A service robot is a robotic system that assists people in their daily lives at work, in their house or leisure and as a part of assistance to the elderly population (Moradi, 2013). Usually, standalone robots are conceived to perform specific tasks, like cleaning, tele-presence, walk support or escorting (see background paragraph for details). On the other side, smart environments and ICT services were typically conceived to monitor the activity of a restricted number of people, and provide personal communications, energy saving, safety and security services.

As introduced, recently standalone robots have been integrated in smart environments to act as simple companion robots (Iwata H., 2009; Banks, 2008) or to provide complex assistive services (Badii, 2009; Cavallo, 2014b). In this new paradigm, called networked robotics (Sanfeliu, 2008), robots provide dedicated services to the users anywhere and anytime, by leveraging the use of wireless communications and the cooperation between robotic agents. Networked robotics is a trend that envisages the distribution of robotics application among a set of processors located inside and outside the robots. Robots cooperate between them and other robotic agents like smart homes and wearable sensors, to improve their sensing and panning capability, in order to provide more complex, acceptable and dependable assistive services. As a consequence robots become an active part of a network completely each other. In this way smart environments and intelligent agents extend the effective sensing range of networked robots improving their planning and cooperation capability (Cavallo F., 2014b; CompanionAble, 2014; GiraffPlus, 2012).

Nevertheless stand-alone and networked robots present limited computing capabilities and they could be not sufficient for continuously supporting daily activities (Kamei, 2012).

Some of these constraints can be overcome by integrating robots with cloud computing resources through the concept of cloud robotics (Goldberg, 2013). This concept leads to more intelligent, efficient and a cheaper generation of robotic networks. Cloud robotics is not a completely new idea; during the 90s Prof. Inaba (Inaba, 1997) conceptualised the remote brain paradigm. The big opportunity to develop and improve this idea is now available (Ferratè, 2013) because of rapid and exponentially growing wireless communications both outside (3G, LTE) and inside the home (Wi-Fi) and recent innovations in cloud computing technologies (Lu, 2014). In addition, smartphone penetration is on the rise all over the world, allowing the possibility to be connected everywhere (Mobile Planet, 2014).

The cloud robotics paradigm extends the concept of multi-robot collaboration, integrating cloud computing resources (Kuffner, 2010). '*In this context, robots are connected to cloud infrastructures for access to distributed computing resources and datasets, and have the ability to share training and labeling data for robot learning'* (Kehoe, 2013). In (Goldberg, 2013) Ken Goldberg emphasised the benefits of the great computation capacity and memory allocation of cloud infrastructures, providing a new form of collective robot intelligence through learning and sharing paradigms. Cloud resources could be used as a way to improve the robot's awareness of surrounding objects and environments, implementing a software repository for everyday objects, images and features, in order to help robots in object recognition and manipulation tasks (LAAS, 2014).

Recently several researches have focussed their efforts into cloud robotic fields (Goldberg, 2014b). For instance, the RobotEarth Project aims to implement a World Wide Web for robots (Hunzinker, 2013). Using RobotEarth architecture robots can store and share information, can offload computational tasks and can collaborate with other robots. The Software as a Service (SaaS) (NIST, 2014) approach allows low cost robots to move computational-intensive data processing to the cloud. In this way, different on-demand computing resources could be added to improve the computational capability of the robots. Du et al. (Du Z., 2011) introduced the concept of Robot as a Service (RaaS) which is conceived to resolve issues on continuity of services. The relationship between users and robotic platforms is mediated by a robot management system that coordinates and selects the proper hardware platform to fulfill user needs and provide the required robotic services. In this model, the user is not required to have a robot, but robots are shared by different users.

The cloud service robotics paradigm extends cloud robotics to AAL fields. In this paradigm, different agents are integrated in order to achieve an efficient, effective and robust cooperation between robots, smart environments and humans. In a user centred design vision, a cloud service robotic paradigm aims to manage different types of robots, in different locations providing tailored and modular services to older persons in a scalable, affordable and reliable manner.

Eventually, technical cloud robotic challenges mainly focus onto five aspects (Goldberg, 2014a):

1. Big data: by means of cloud storage, robotic agents, but also other ICT technologies, have access to a vast amount of data, such as a library of images, maps and object data.
2. Cloud computing: this technology offers grid computing on demand for statistical learning and motion planning guarantying the quality of service.
3. Open source data and code: robotic agents, like humans, will share information and algorithms.
4. Collective robot learning: the data collected by different robotic platforms or other agents could be analysed by means of machine learning algorithms.
5. Crowdsourcing: robotic agents could access also the vast amount of information available on the internet and retrieve on demand human guidance for evaluation, learning and error recovery.

Therefore these aspects are mainly related to the technology part. But when researchers design and implement innovative ICT solutions to support senior citizens, they have to take into account also other aspects related to society and market. In this way, the acceptability and usability level will increase and, consequently, the time-to-market of a specific technology will decrease.

The technology should be designed to be pervasive, modular and custom. The user should be immersed in technology, in a transparent way without being invasive, to be supported in each aspect of his/her daily living. In the near future, in a smart city context, the integrated technology solutions should support citizens offering different services according to their needs such as energy, traffic and health management. For instance senior citizens could use this service to be part of the community, promoting their active social inclusion, to be aware of their health status connecting with other care stakeholders.

These systems should be developed and implemented very close to humans, with some peculiarity of human beings, in order to achieve the next generation of cloud social robotics. The future service should be designed passing from user centred design to society centred design, taking into account acceptability, usability and legal and ethical issues. This integration is not only a matter of technical issues, but should be the result of synergic action of issues coming from different fields. Cloud social robotics should cover also aspects related to the friendliness of technology, the communication and integration between different devices and the integration of common human-machine interfaces to control new services in order to reduce the multiplication of multiple interfaces (one interface-multiple technologies).

CONCLUSION

Eventually, the aim of this chapter was to describe how demographical and societal challenges related to the aging population and the increasing demand of nurse practitioners can be addressed and optimised by the integration of ICT and robotic technologies in a smart environment. The concrete experience of RoboTown Living Lab has been reported and discussed in order to describe how technological barriers can be overcome. Furthermore, at the end of the chapter, the authors gave some advice and recommendations for future design of new services based on AAL technology.

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KEY TERMS AND DEFINITIONS

3-D Robotic Service: a paradigm where robots are integrated in different smart environments and coordinated by intelligent agents over the cloud infrastructure to provide continuous services to citizens.

Cloud Robotics: integration of robotics with cloud computing resources. This paradigm led to a new generation of robotics. Through the cloud, robots can share knowledge, data and algorithms.

Cloud Service Robotics: a paradigm which extends cloud robotics to AAL fields. In this paradigm, different agents are integrated in order to achieve an efficient, effective and robust cooperation between robots, smart environments and humans.

Living Lab: a user centred and open-innovation ecosystem to promote social innovation. It operates in a territorial context where research centres, industries and social organisations active in the area cooperate together to provide innovative service. Here the citizens can be an active part of the innovation process.

Ageing Well: defined as continued independence with good self, rated health and psychological well being. Applied to the ageing process, independent living could be called ‘Ageing in place’, insisting on accompanying the ageing process so persons have not to change drastically their environment or move from it because of some loss of functions or mobility abilities, or health problems.

Service Robotics: robotic systems and services, which proactively act for assisting, monitoring and providing well-being of elderly or not self-sufficient people in assisted environments.

Acceptability: it is the combination of all factors that influence technology adoption or rejection by society.